

Indicators of Ecological Change

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A SERDP Ecosystem Management Project (SEMP)
being implemented at Fort Benning, GA

SEMP Technical Advisory Committee Meeting
October 2003

Participants

- Jack Feminella and Kelly Maloney, Department of Biological Sciences, Auburn University — [Stream macroinvertebrates](#)
- Thomas Foster, Anthropology Department, Pennsylvania State University — [Historical land cover](#)
- Patrick Mulholland, Environmental Sciences Division, Oak Ridge National Laboratory — [Aquatic ecology](#)
- Lisa Olsen, Environmental Sciences Division, Oak Ridge National Laboratory — [Geographic information and landscape analysis](#)
- David White, Aaron Peacock, and Sarah McNaughton, Center for Environmental Technology, University of Tennessee — [Soil microbiology](#)
- Sharon Hermann and Dan Wyrick, Department of Biological Sciences, Auburn University — [Terrestrial indicators](#)
- Virginia Dale, Environmental Sciences Division, Oak Ridge National Laboratory — [Terrestrial and landscape indicators, integration](#)

Objectives

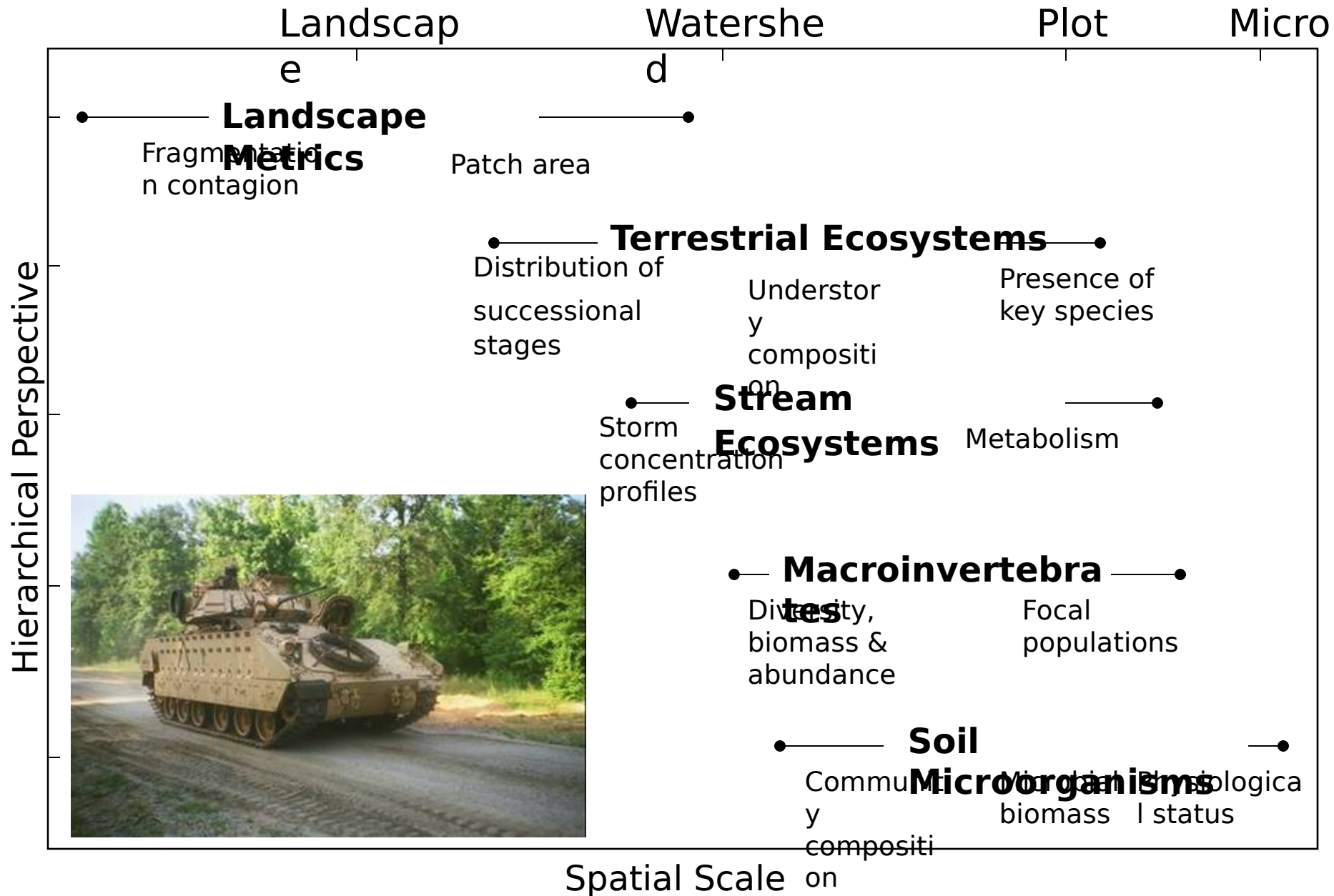
- ! To identify indicators that signal ecological change in intensely versus lightly used ecological systems.
- ! To ensure that these indicators are feasible for the installation staff to measure and interpret and thus can become a part of the ongoing monitoring system at the installation.



Technical Approach

- (a) Analyze historical trends in environmental changes to identify potential indicators;
- (b) Collect supplemental data relating to proposed indicators (building upon existing data);
- (c) Perform experiments to examine how training affects indicators;
- (d) Analyze resulting set of indicators for appropriateness, usefulness, and ease of taking the measure;
- (e) Develop and implement a technology transfer plan.

Suite of Ecological Indicators

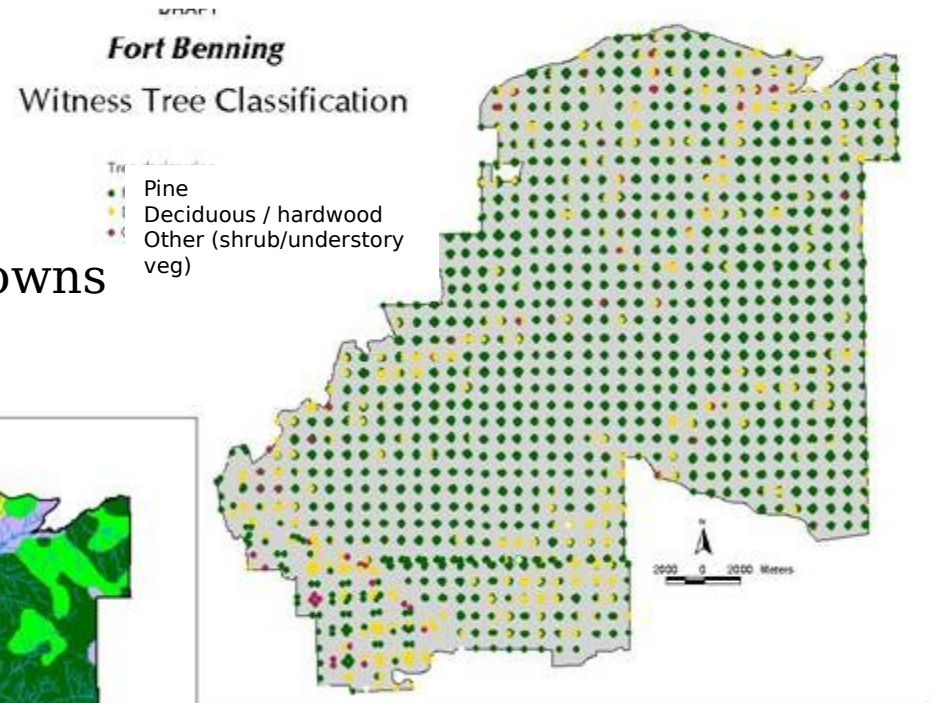
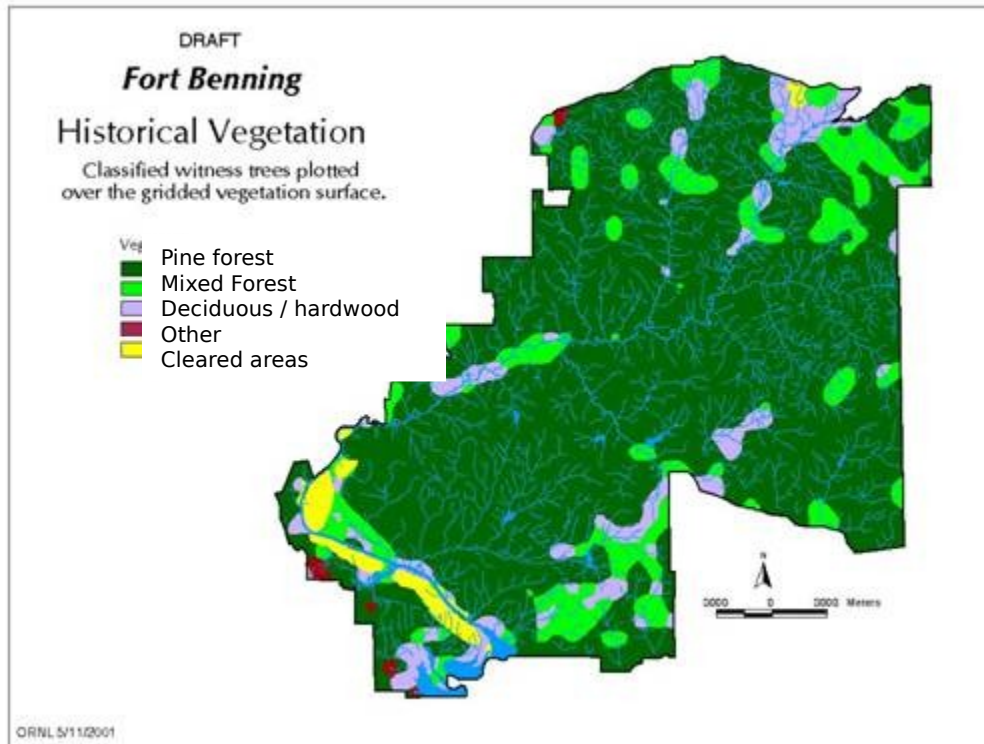


Technical Approach: Landscape Studies

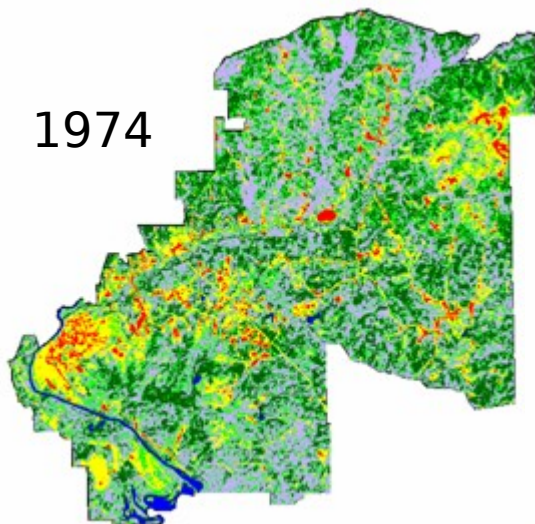
- Explore data availability
- Develop comparable data sets over time (1837 to present)
- Analyze changes in pattern and distribution of land cover over time
- Determine which landscape metrics are most useful for indicating change

Fort Benning Historical Vegetation - 1827

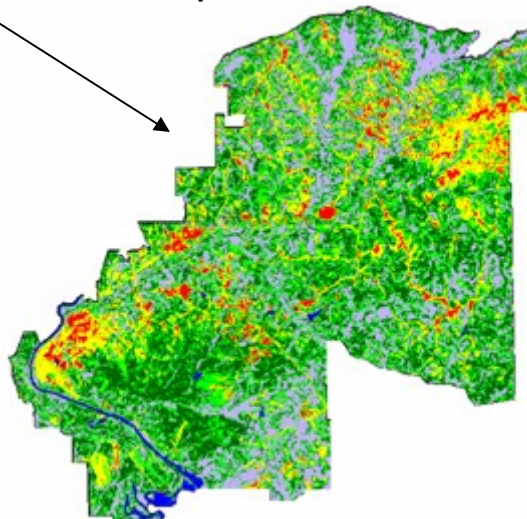
1. Witness tree data
2. Tree classification
3. Interpolation of surface
4. Estimation of cleared areas- large settlements/towns



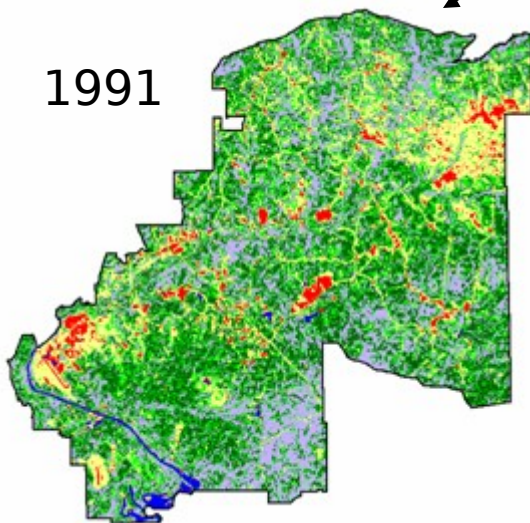
1974



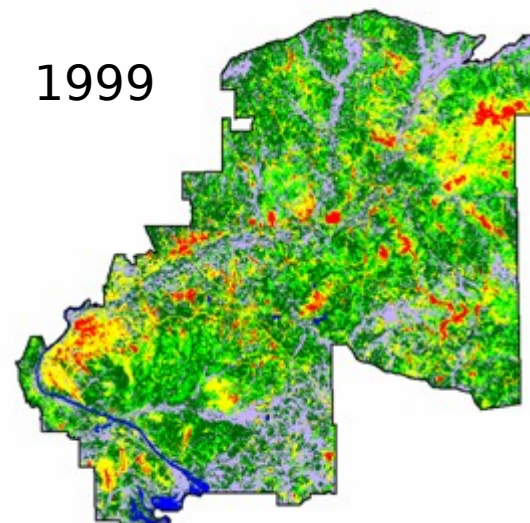
1983/86



1991



1999



**Ft. Benning
Land Cover Classification Key**

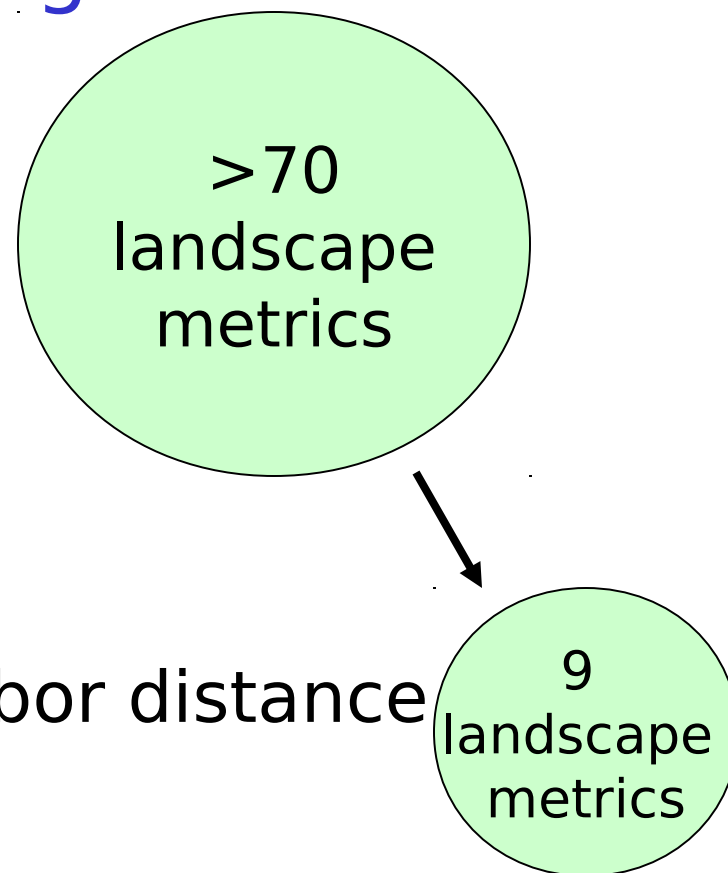
- Bare ground or developed areas
such as buildings.
(highly reflective surfaces)
- Non-forest or cleared areas.
(ground cover present, includes lawns)
- Deciduous forest (dense)
- Mixed forest (areas of deciduous
and pine, widely spaced or sparse
forest cover and transitional areas
between forest and non-forest)
- Pine forest (dense)
- Water

Major Results

- **Vegetation maps developed from different data sources can be compared**
- **Changes over time occurred in the vegetation at Forest Benning**
 - 1827 to 1974
 - Percent cover of forest declined
 - Pine coverage decreased
 - Increase in deciduous, mixed and nonforest cover
 - 1974 to 1999
 - Gradual increase in the nonforest vegetation (esp. on slopes)
 - Decline in cover of forest vegetation
 - Increase in pine cover
 - Decrease in deciduous cover

The most useful metrics for distinguishing changes in land cover classes at Fort Benning

- Percent cover
- Total edge (with border)
- Number of patches
- Mean patch area
- Patch area range
- CV of patch area
- Perimeter area ratio
- Euclidean nearest neighbor distance
- Clumpiness



[Choice of metric depends on question]

Sampled vegetation and soil microbes in five discrete land-use types

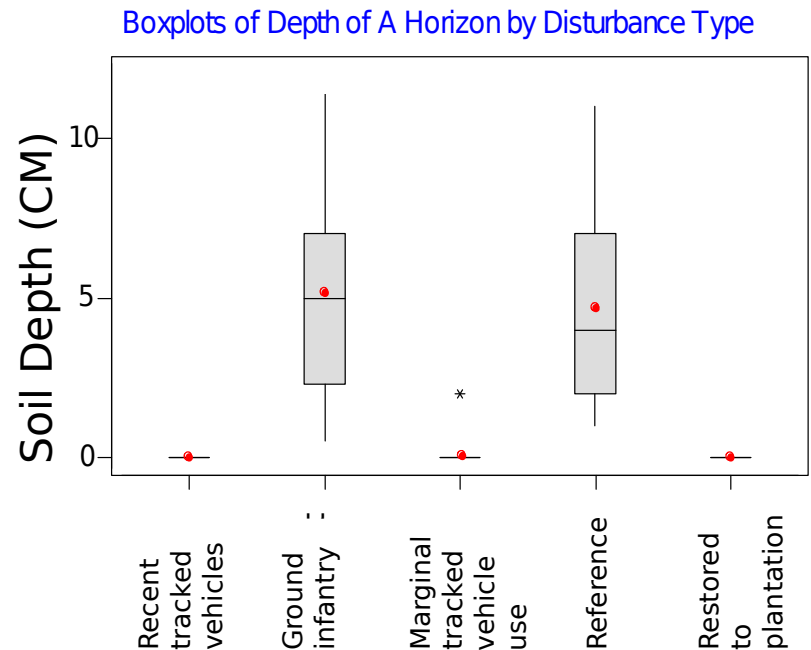
(based on observations and experience of Fort Benning staff)

- Reference
- Ground infantry
- Marginal to tracked vehicles use
- Recent tracked vehicle use
- Restored to plantation



Terrestrial Indicators

- Overstory
 - Maximum tree age
 - Canopy cover
- Understory
 - Percent cover by life form
 - Percent cover by plant f
- Soils
 - Depth of A horizon
 - Soil microbial attributes determined by lipid biomarker analyses)
 - Biomass
 - composition



Narrowed List of Plant Indicators

All plant species
and life forms



All plant families
and life forms

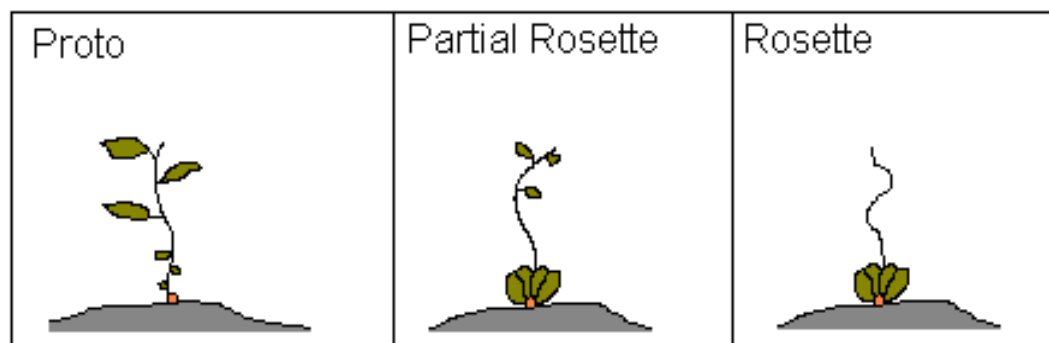


Select plant
families and
life forms

Transfer of Information

Plant Families and Life Forms Seen in the Fort Benning Area: A Field Guide

Hemicryptophytes Ground level buds



Analysis of soil microbial community

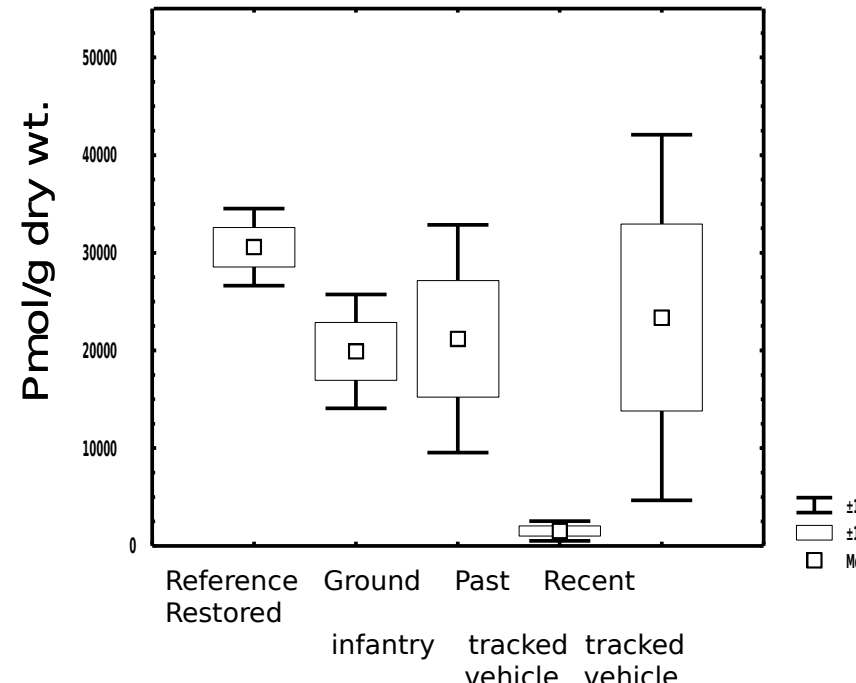
- **Benefits:**

- **Easy collection of soil cores**
- **Ship frozen**
- **Base or commercial laboratory for analysis**
- **Readily interpretable definition and potential for reversibility**

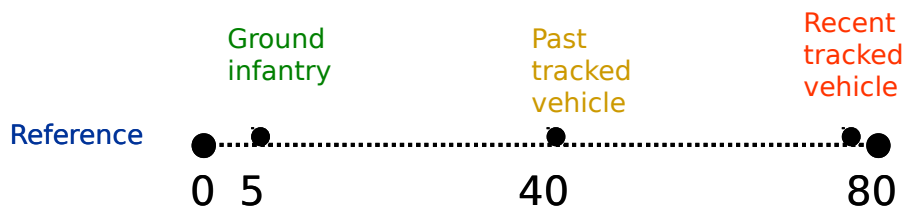
(Soil microbiota do not require biological expertise to interpret)



Microbial Biomass PLFA



Generalized Squared Distances Between Groups



Experiment Established in K11

Pre- and post-disturbance monitoring

- Canopy characteristics
- Understory vegetation
- Soil microbial community
- Storm water runoff
- Benthic invertebrates
- Erosion



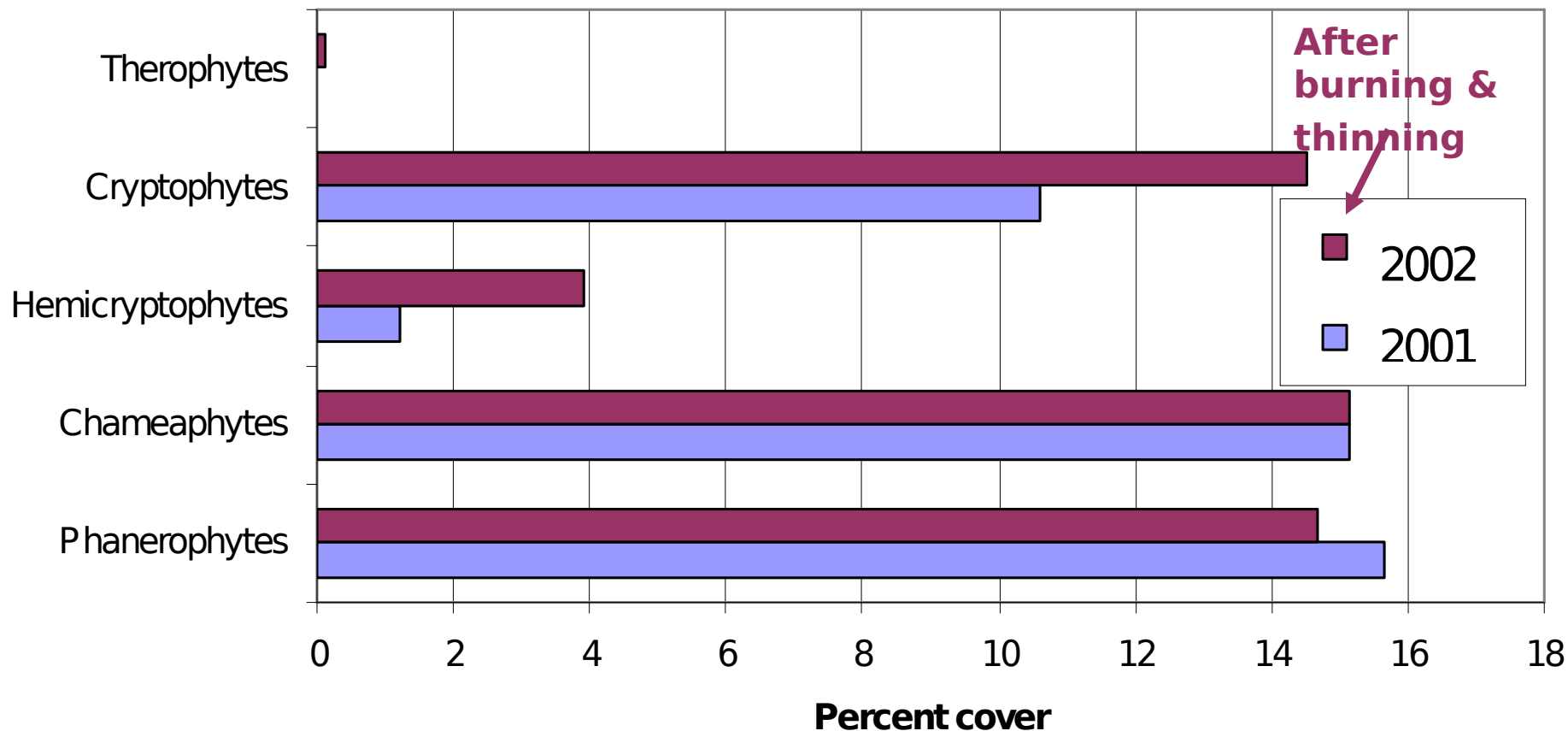
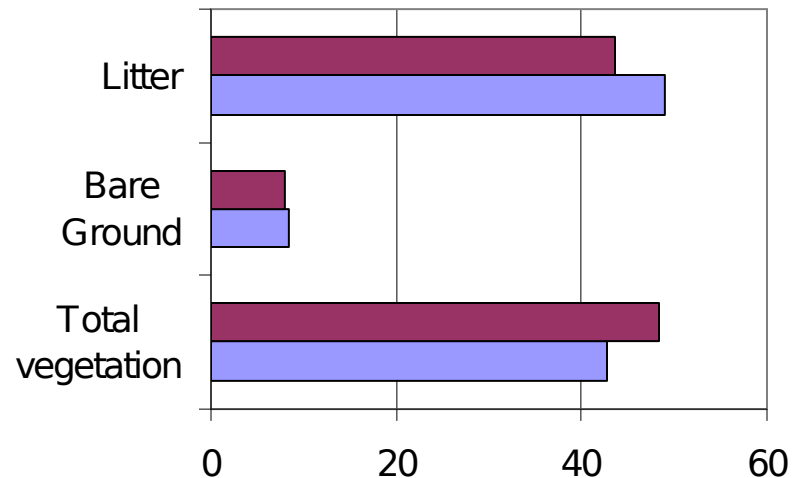


Experiment for Testing of Indicators

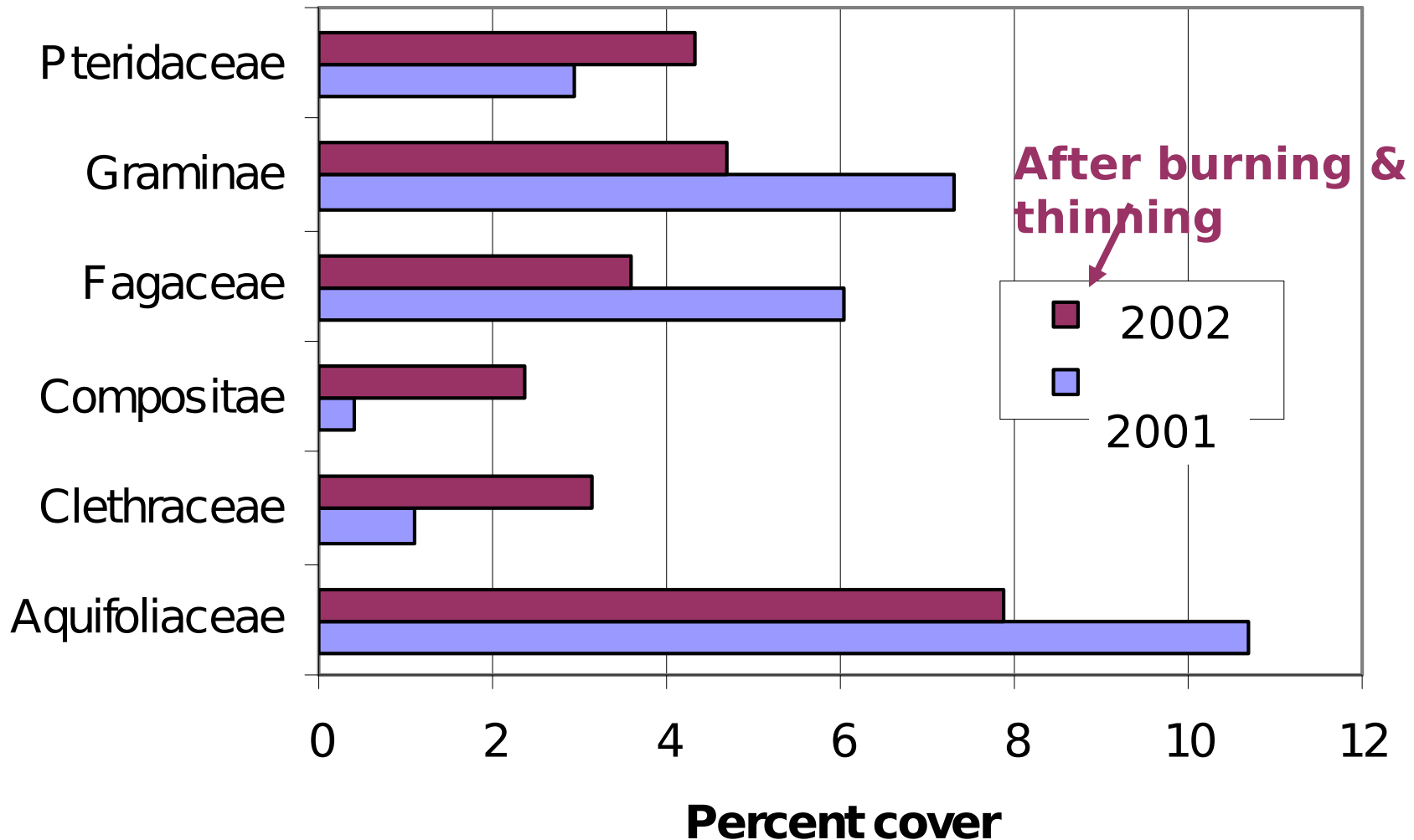
- Jan 2001 - K11 site selected
- Feb 2001 to April 2002-
baseline data collected
- May 2002 – Understory fire →
- June to Oct 2002- Post-fire data
collection
- Oct or Nov 2002 – Thinning
- Dec 2002 to Oct 2003 – Post
thinning data collected
- May 2003 – Tracked vehicle
disturbance
- June 2003 to present – Post
disturbance data collection



Life form differences at K11 Experimental Site



Plant families with major differences



Technical Approach: Stream Studies

Objective

Develop and evaluate potential indices of land-use effects on catchment biogeochemistry and stream ecosystems

Approach

Land-use gradient analysis (land-use intensity quantified at catchment scale as % land denuded)

- Stream sites (2nd-3rd order) over range of land-use intensity
- Measure potential indices across land-use gradient
- Develop relationships between indices and land-

Potential Stream Indices of Land Use

1. Storm chemistry profiles

Measurements: NH_4 , NO_3 , PO_4 , Cl , SO_4 , electrical conductance, suspended sediments over storm hydrographs

Analyses: concentration vs. discharge relationships, peak concentrations

2. Diel dissolved oxygen profiles (metabolism indicator)

Measurements: dissolved oxygen concentrations and deficits at 30-min intervals during baseflow

Analyses: diurnal amplitude, night-time minima

3. Macroinvertebrate communities and habitats

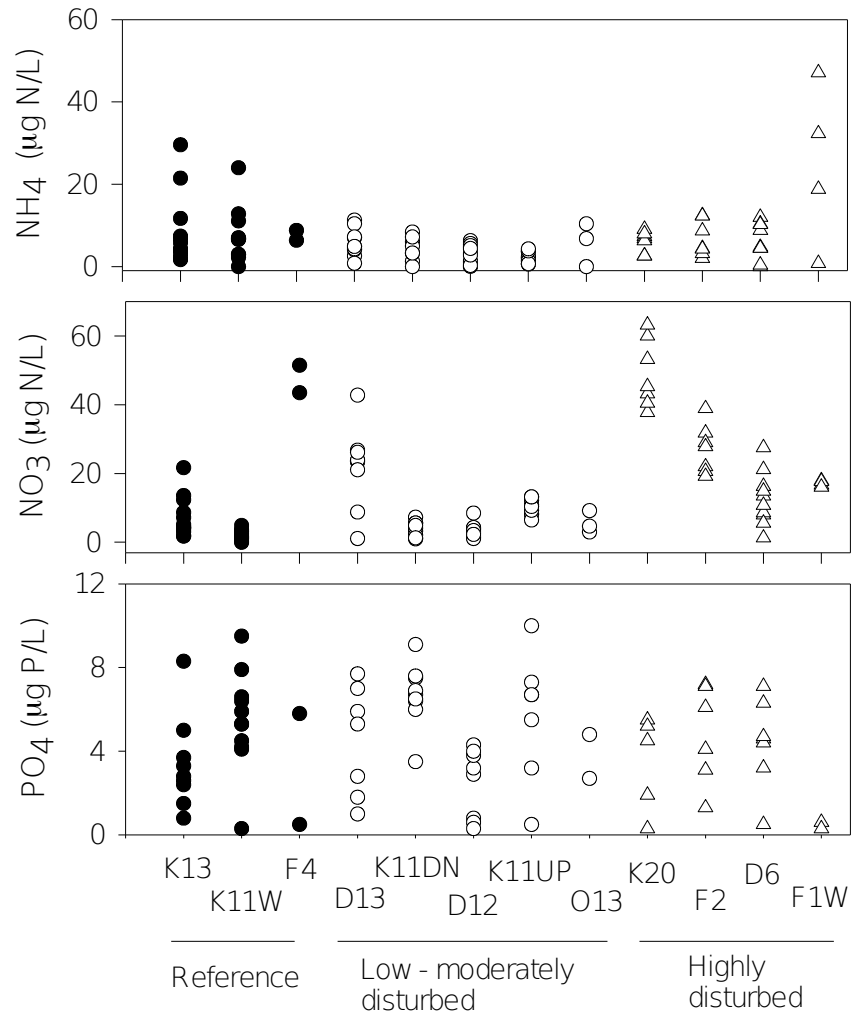
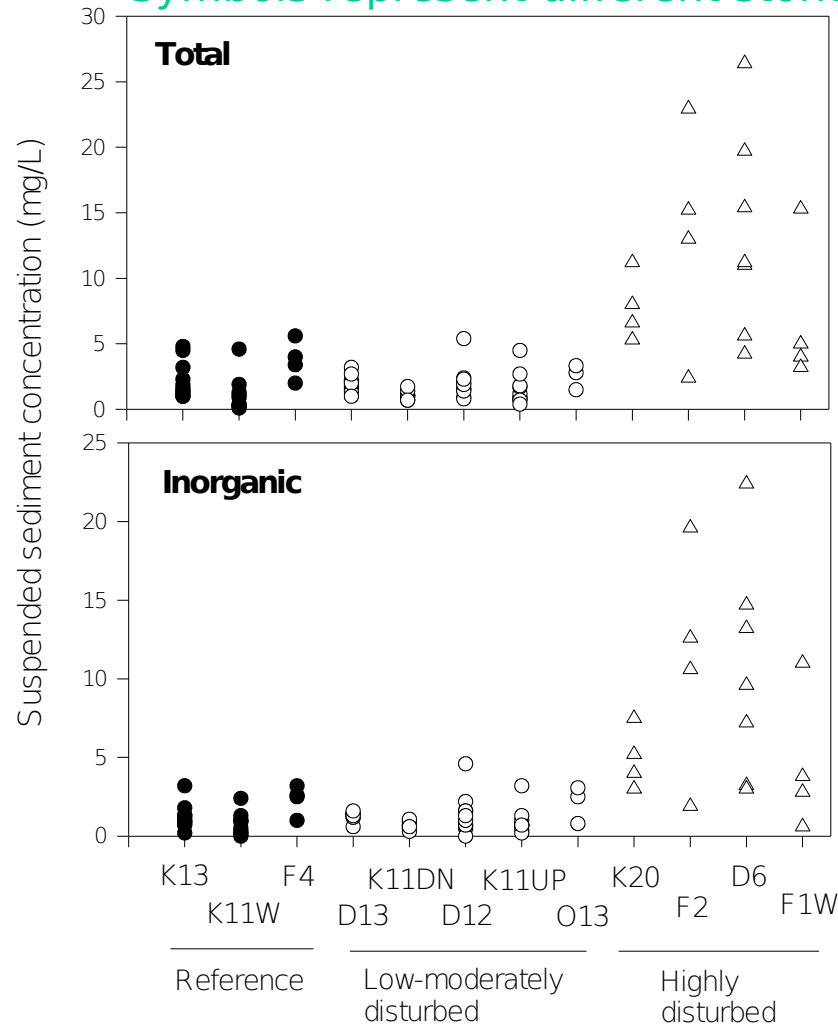
Measurements: numbers, biomass & diversity of benthic macroinvertebrates, bedload sediment movement

Analyses: EPT index, sensitive species abundance, NCBI index, similarity indices, sediment movement over time

Baseflow suspended sediment concentrations are a good indicator of land use

But baseflow nutrient concentrations are not

Symbols represent different storms.



Effects of Landscape Disturbance on Streams



Disturbance



**Sediment,
Organic Matter,
Nutrient Runoff**



**Altered Abundance
&
Diversity**



**Altered Functional
Organization**

Biota



Selective Harvest

Hugh Westbury



Roads

Jeff Houser



Controlled Burn

Hugh Westbury



Controlled Burn

Hugh Westbury



Ephemeral Channel



Danny Johns

Ephemeral Channel



Danny Johns

Road "Blow-out"



Overland Flow

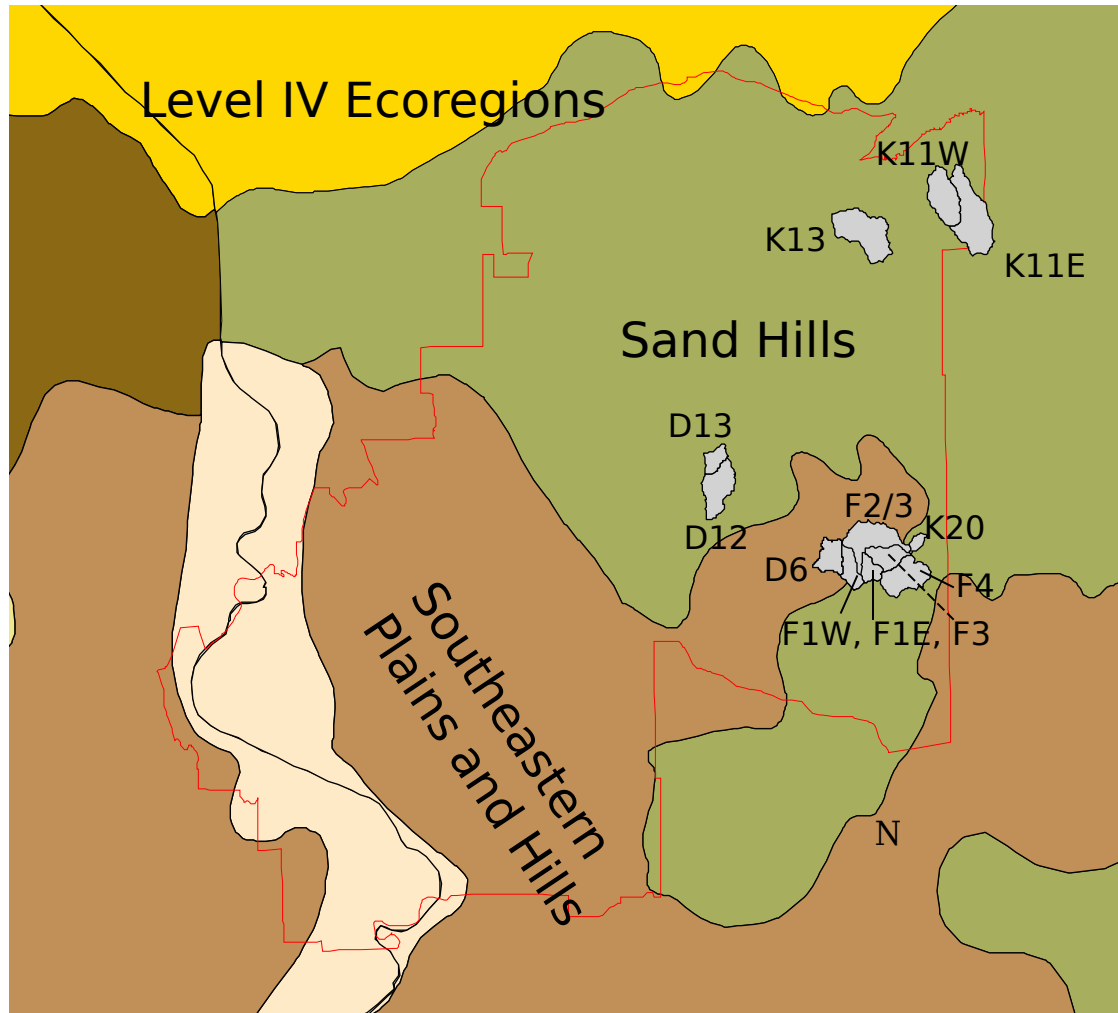


Danny Johns



Sediment Source

Study Site – Fort Benning Military Reservation, Georgia



Objectives

- Relate landscape disturbance with stream physical structure and biotic communities
- Develop aquatic indicators of landscape disturbance in Ft. Benning streams

Methods

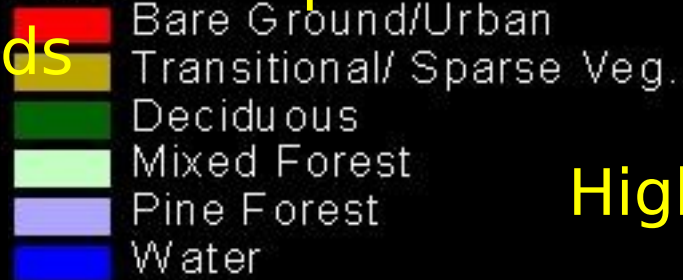
Quantified landscape disturbance – GIS/Landsat imagery

Disturbance Intensity (DI) - % watershed that is

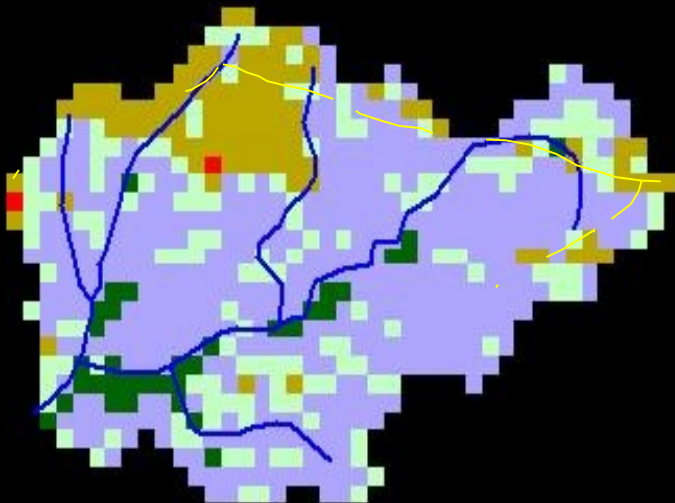
Bare Gro

opes > 3% and under

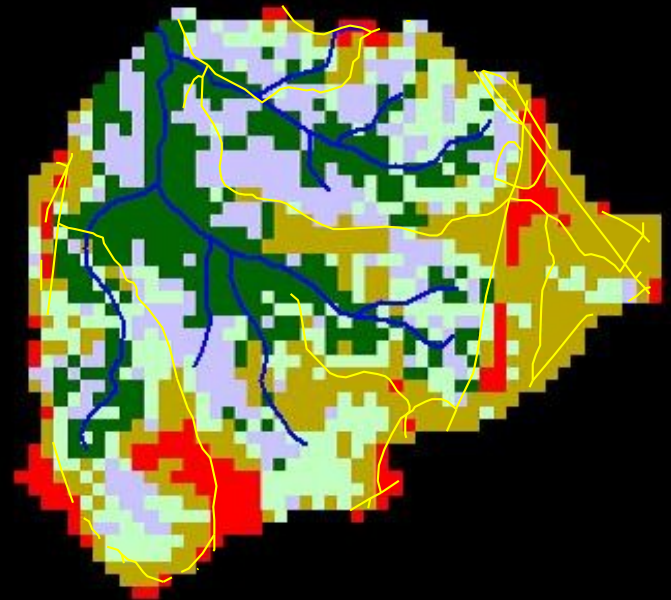
Roads



Low



High



Quantify:

- Physical structure / Habitat:
 - Streambed stability
 - Streambed organic matter
 - Coarse woody debris
- Stream Biota:
 - Macroinvertebrates
 - Fish
 - Algae

Scour Pin

Hester-Dendy
multiplates



CWD
sampling



Algal
sampling

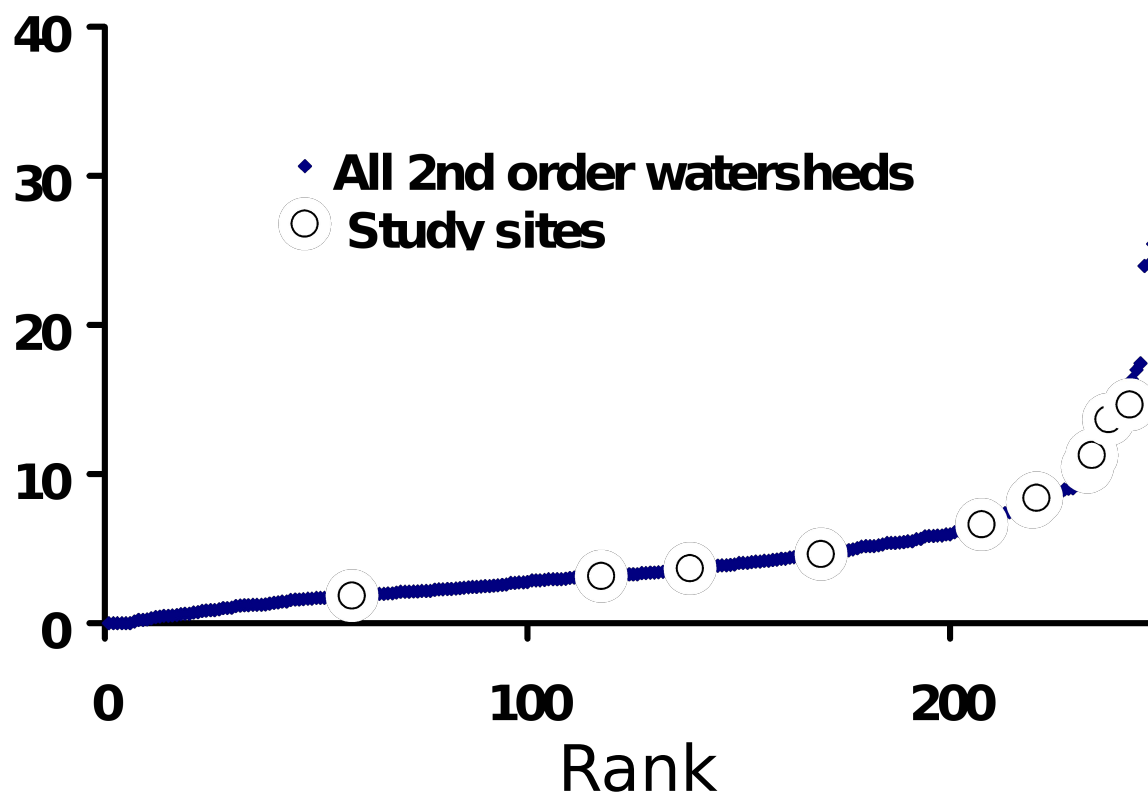


Electroshocking
(fish, crayfish)



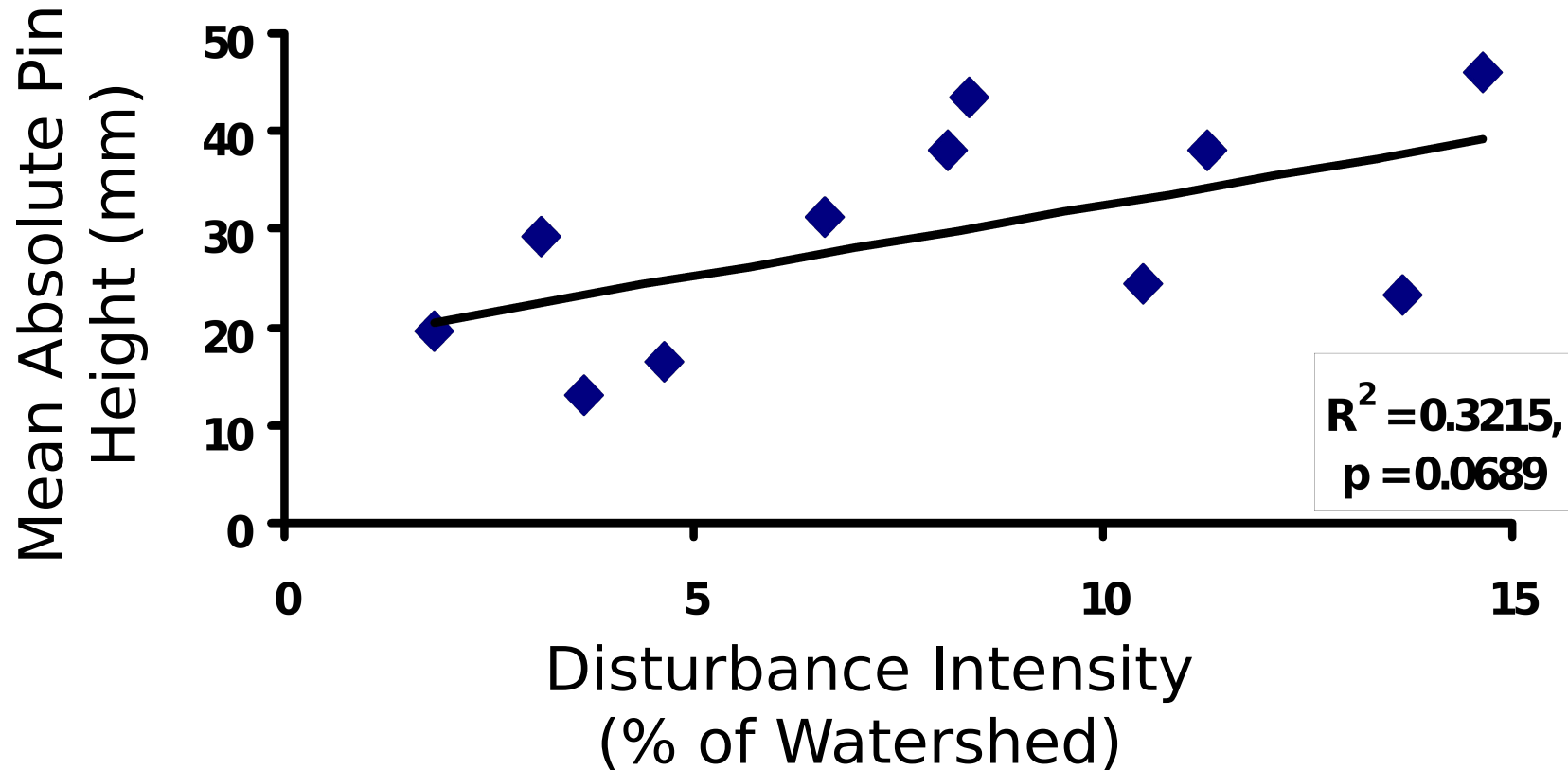
Disturbance Intensity of Study Sites

Disturbance Intensity
(% of catchment)

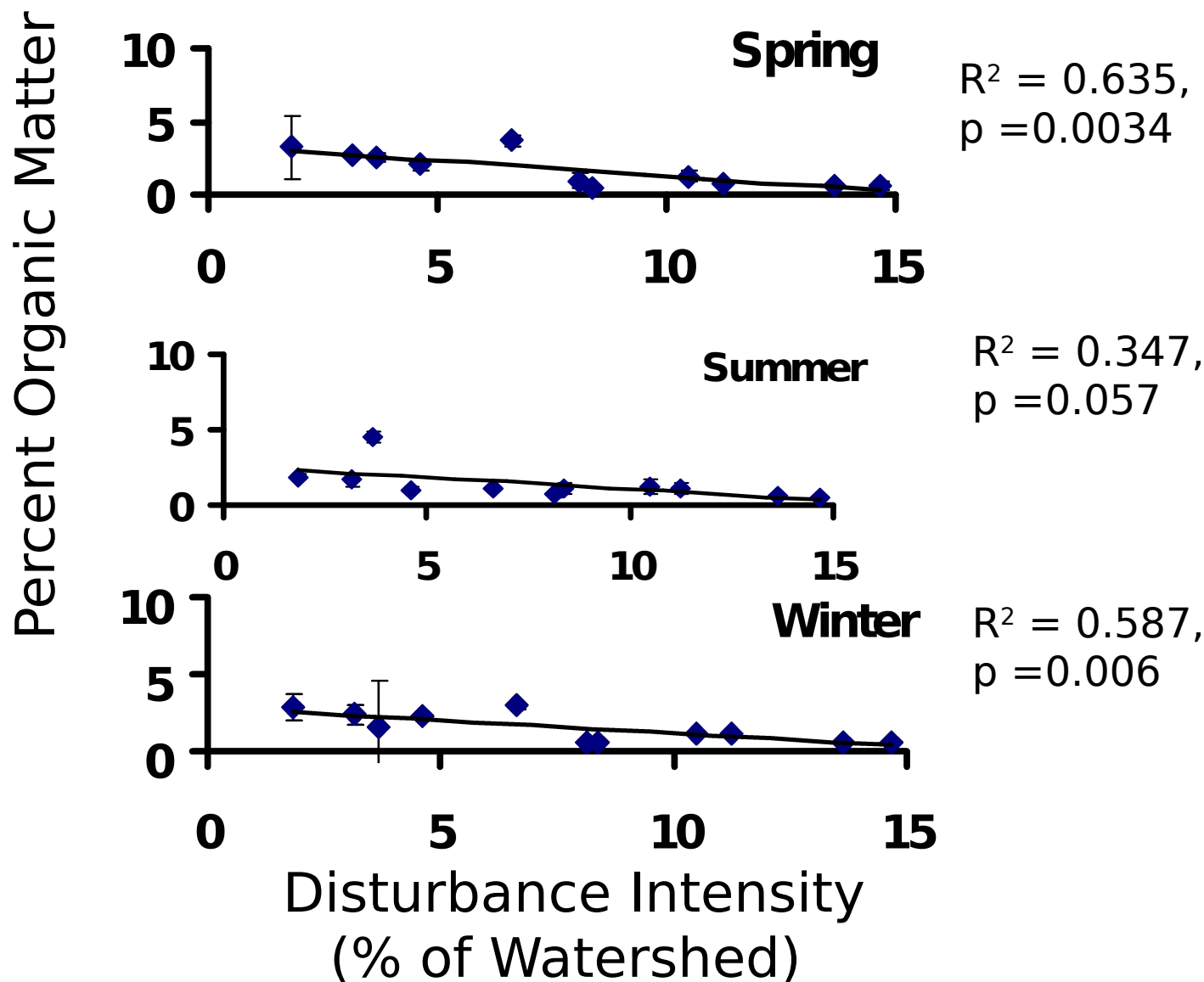




Streambed Instability

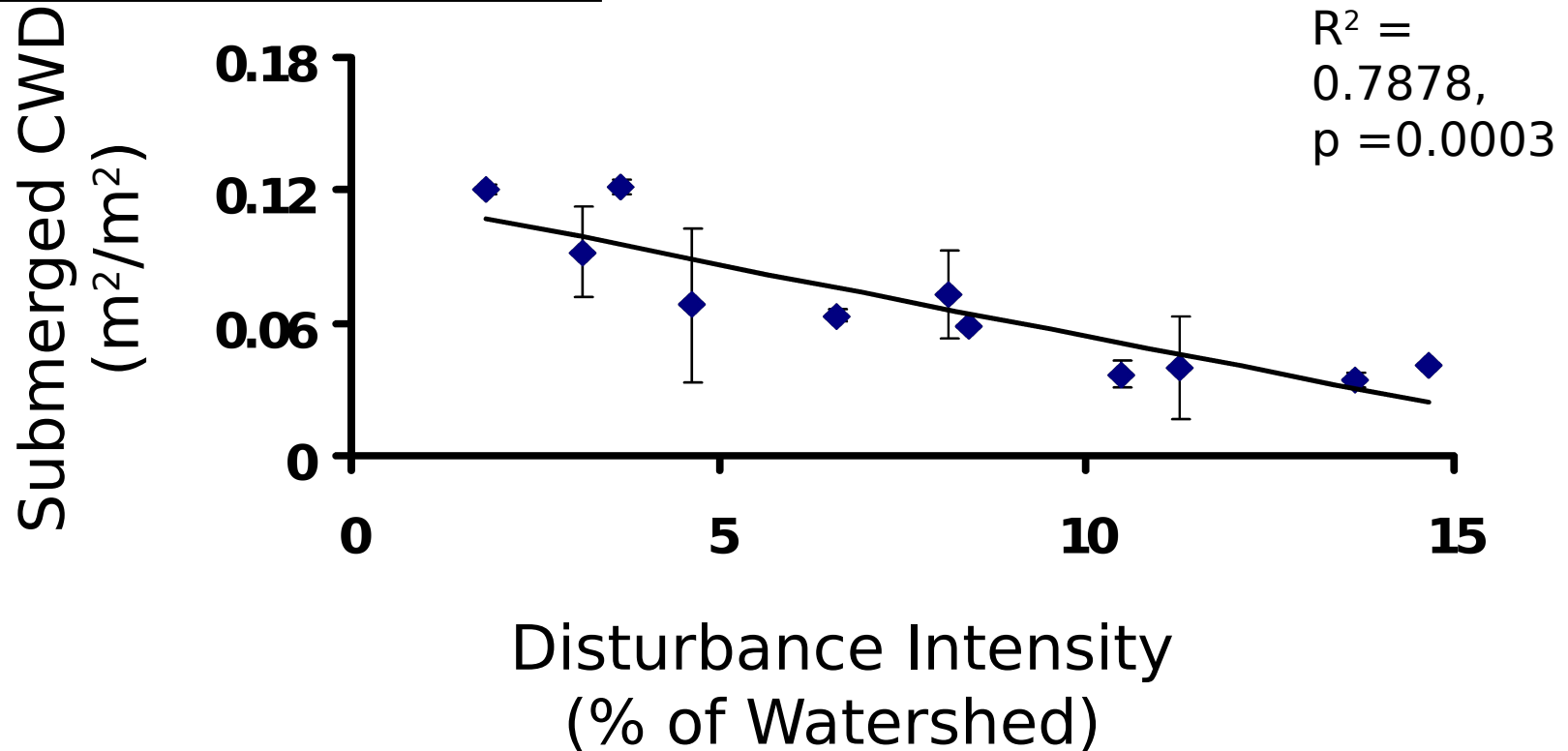


Streambed Organic Matter



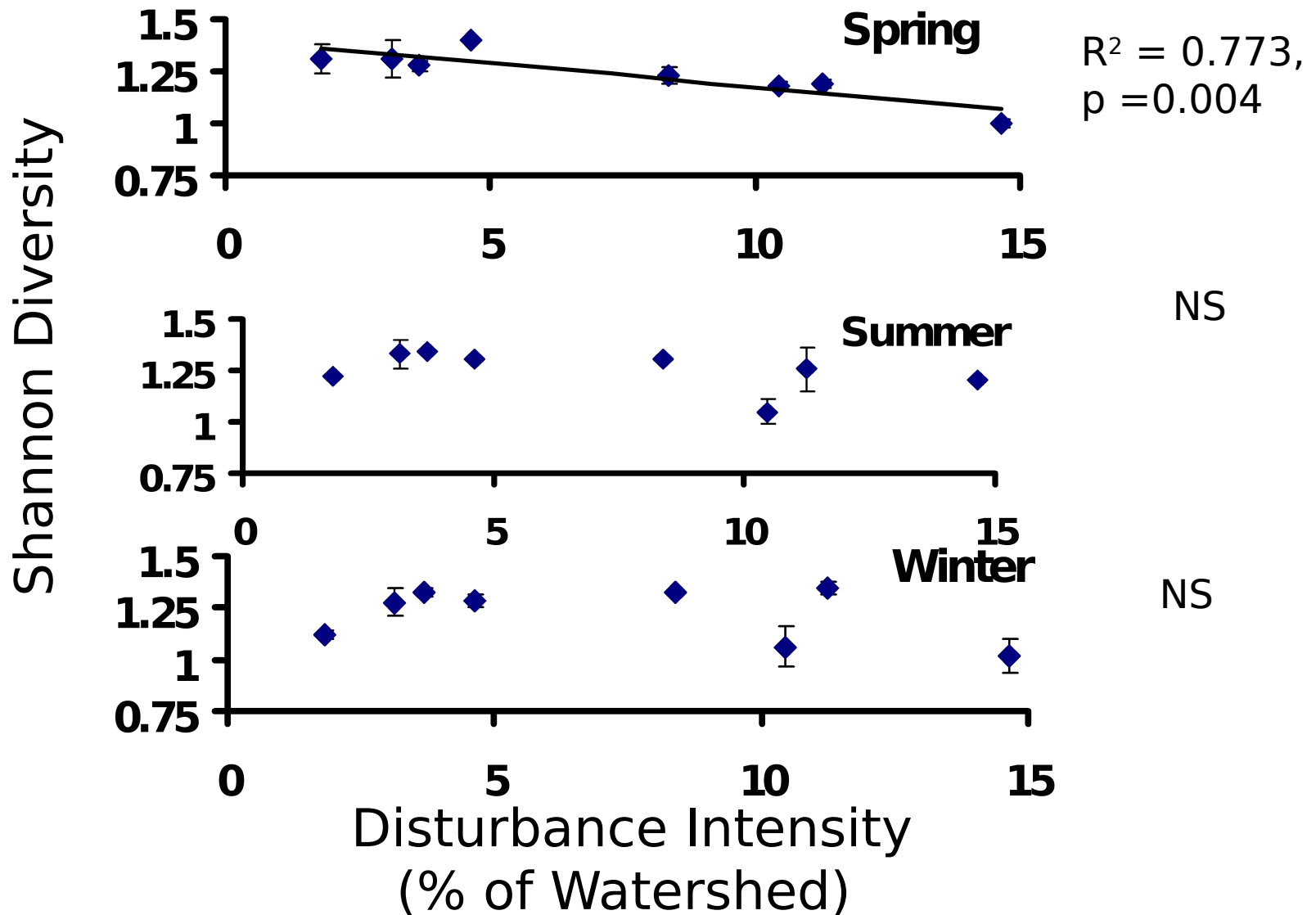


Submerged Coarse Woody Debris



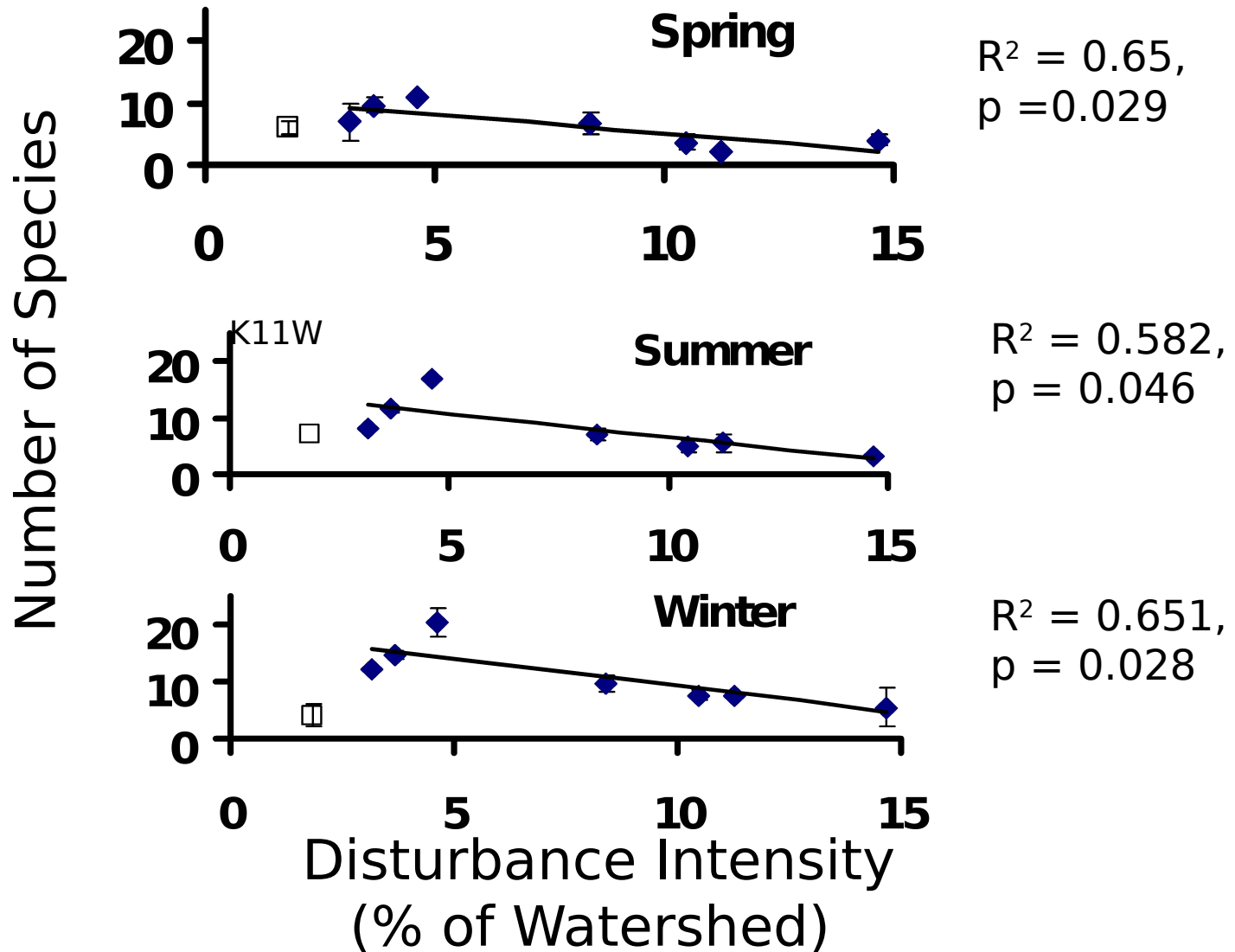


Macroinvertebrate Diversity



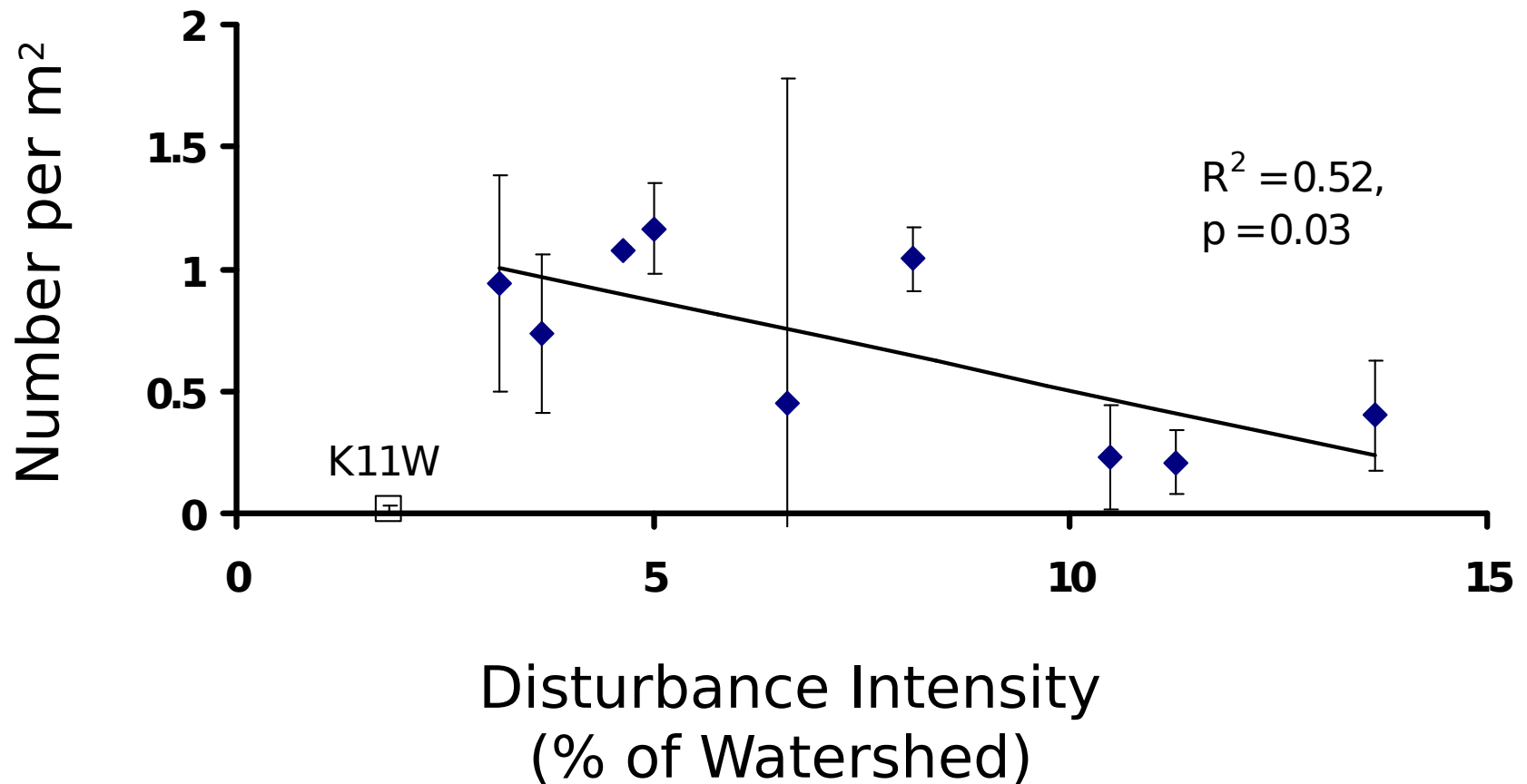


Number of EPT Taxa



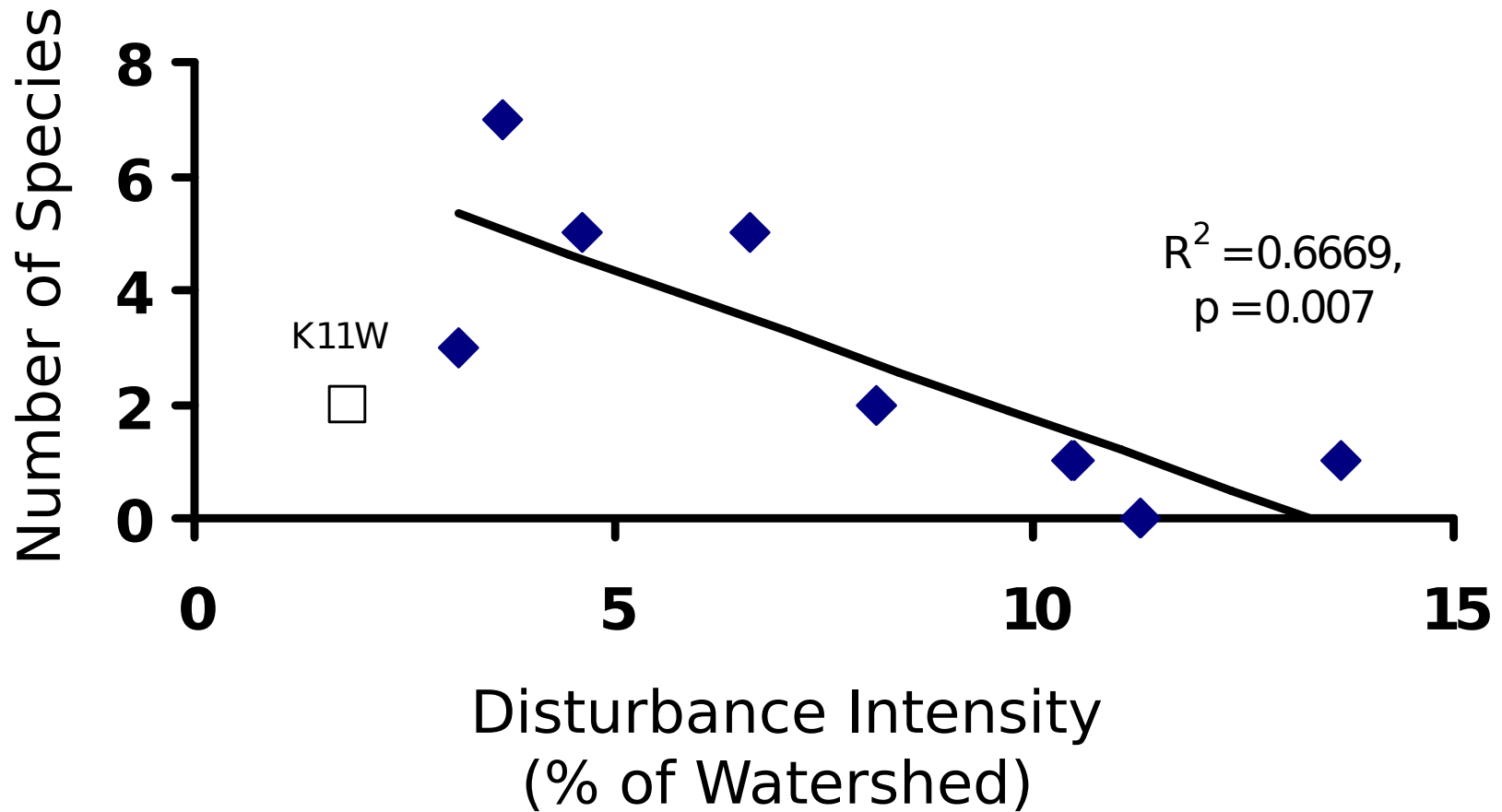


Density of *Procambarus versutus*





Fish Species Richness (Spring 2003)



Summary

- Land use patterns reflected by stream abiotic and biotic components
- Landscape disturbance affected:

Habitat:

- Decreased streambed stability
- Decreased organic matter
- Decreased coarse woody debris

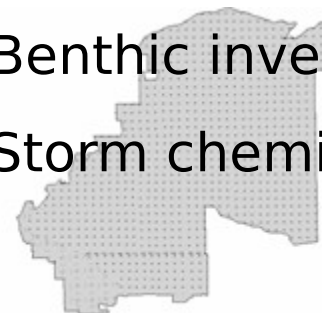
Stream biota:

- Decreased macroinvertebrate diversity,
- Decreased EPT taxa
- Decreased fish species richness

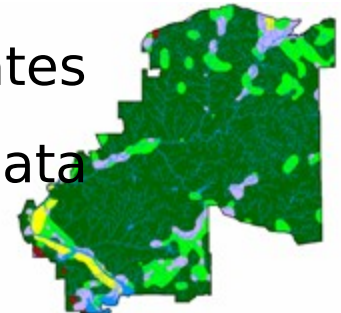
Ongoing Analyses

- Functional feeding group (macroinvertebrates and fish)
- Biomass relationship (both macroinvertebrates and fish)
- Biotic indices
 - North Carolina Biotic index (NCBI)
 - Georgia Index
 - Fish Index of Biotic Integrity (IBI)

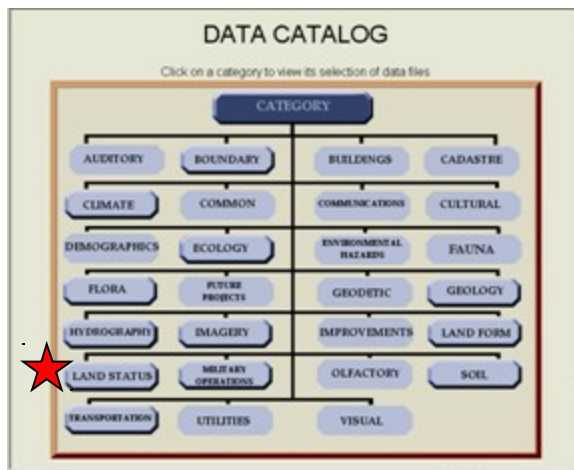
- Landscape data
- Understory vegetation
- Microbial Community
- Benthic invertebrates
- Storm chemistry data



Witness Tree - Point Data



Historical Land Co



Coordination with other SEMP and SERDP projects

- **Garten and Ashwood** (soil carbon and nitrogen)
- **Collins and Dilustro** (soil respiration, temperature and moisture)
- **Ustin and Olstead** [hyperspectral data (primarily AVIRIS) to map and model the spread of invasive weeds]
- **Mulholland** (co-location of steam sampling sites)

Products

Publications:

- 7 Journal, national or international (published or in press)
- 1 Book chapter
- 2 Other

Presentations:

- 29 Professional meetings
- 8 Other meetings

Contributions to Other SEMP Projects

- Criteria for selecting a suite of indicators
- Protocol for selecting indicators
- Data from our studies on indicators: terrestrial, stream, and soil microbes
- Historical vegetation map
- Disturbance experiment

Coordination with Other SEMP Projects

- Baseline information provided by ECMI and LCTA
- Co-location of sampling sites and sharing of data with other SEMP projects
 - Storm hydrological chemistry
 - Stream macroinvertebrates
 - Soil samples
- A comprehensive picture of changes in microbial community structure